MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2018/2019

ETM7126 - SATELLITE COMMUNICATIONS

M.Eng. (Telecommunications)

27 MAY 2019
2:00 PM – 5:00 PM
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages (including this cover page) with 4 Questions only and two Appendixes.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Give a satellite link budget analysis by answering the following questions based on the information that follows. The value of Boltzmann constant is provided in the appendix.

(i) Uplink carrier-to-noise power spectral density, $(C/N_0)_U$. [4 marks]

(ii) Downlink carrier-to-noise power spectral density, $(C/N_0)_D$. [3 marks]

(iii) Overall carrier-to-noise power spectral density, $(C/N_0)_T$. [4 marks]

(iv) Consider the transmission of digital data using Quadrature Phase Shift Keying (QPSK), with a probability of symbol error, $P_e = 1 \times 10^{-5}$. Calculate both the permissible **symbol rate** and **bit rate**.

Hint: For QPSK, $P_e \approx erfc[(E_s/N_o)^{1/2} \sin(\pi/4)]$, where E_s/N_0 is the energy-per-symbol-to-noise-spectral-density ratio and $erfc(.)$ represents the complementary error function whose values are tabulated in the appendix.

[6 marks]

Uplink

Frequency, f_U	6 GHz

Satellite transponder

Input back-off, *IBO*	-25 dB
Output back-off, *OBO*	-20 dB
Power flux density at saturation, ϕ_{sat}	-95 dBW/m^2
Figure of merit, $(G/T)_S$	16 dB/K
EIRP at saturation, $EIRP_{sat}$	45 dBW

Downlink

Frequency, f_D	4 GHz
Total loss in the downlink, L_D	185 dB

Receiving earth station

Figure of merit, $(G/T)_{ES}$	18 dB/K

(b) How would the choice between geostationary (GEO) satellite and low earth orbit (LEO) satellite affect the design in both the earth station and the satellite system? [8 marks]

Continued ...

Question 2

(a) (i) Explain the difference between solar time and sidereal time.

[4 marks]

(ii) Prove that a sidereal day is 23 hours 56 minutes 4.09 seconds.

[4 marks]

(b) Show that the round trip delay (RTD) between an earth station and a geostationary satellite is close to ¼ second, given that the satellite is required to be at an elevation angle larger than 10 degrees. The values of the gravitation parameter and mean Earth radius are given in the appendix.

[8 marks]

(c) What are the important requirements in the design of an earth station antenna?

[4 marks]

(d) What are the main radio frequency (RF) and intermediate frequency (IF) components that are used in an earth station? Show the interconnections among them in a simple sketch of the organization of an earth station.

[5 marks]

Question 3

(a) Consider a satellite transponder for a 250-channel frequency division multiplexed (FDM) telephony system (4 kHz per voice channel) with the details given below:

RMS deviation of 0 dBm test tone, Δf_{rms}	: 350 kHz
Multi-channel peak factor, g	: 3.2
Maximum baseband frequency, f_{max}	: 1000 kHz
Guard band	: 10% of the occupied bandwidth
Required signal-to-noise power ratio, S/N	: 50 dB
Pre-/de-emphasis gain, P	: 3 dB
Noise weighing factor, W	: 2.5 dB

Determine the followings:

(i) Required RF bandwidth.

[5 marks]

(ii) Carrier-to-noise power ratio, C/N.

[4 marks]

Some useful formulas are provided in the appendix.

Continued ...

Question 3 (continued)

(b) An earth station employs a 4 m diameter antenna operating at 12 GHz. The antenna has an efficiency of 0.8 and a noise temperature of 40 K. It is connected through a feeder (at 300 K) having 0.5 dB loss to a receiver. The receiver has a noise figure of 3 dB. Room temperature is 290 K. Calculate the figure of merit (i.e. the G/T ratio) of the earth station. You can refer to the appendix for some useful formulas if necessary.

[8 marks]

(c) Briefly discuss both the advantages and disadvantages of frequency division multiple access (FDMA) and time division multiple access (TDMA) in the context of satellite communications.

[8 marks]

Question 4

(a) A satellite TV company launches its satellite into the geostationary orbit. The company intends to introduce Very Small Aperture Terminal (VSAT) as the receiving earth station. Explain why VSAT technology suits this application.

[6 marks]

(b) Briefly sketch and describe the different types of satellite multibeam patterns.

[6 marks]

(c) In setting up digital data links between a satellite and multiple earth stations, you have to choose between frequency division multiple access (FDMA) and time division multiple access (TDMA) techniques. What are the points of consideration in the decision making?

[7 marks]

(d) Explain about the Global Positioning System (GPS).

[6 marks]

End of Questions

APPENDIX I

Gravitation parameter, μ	=	3.986×10^{14} m^3/s^2
Mean Earth radius, R_E	=	6378 km
Speed of light, c	=	3×10^8 m/s
Sidereal day	=	23h 56m 4.09s
Boltzmann constant, k	=	1.379×10^{-23} J/K = -228.6 dBW/Hz K

Antenna

Effective isotropic radiated power, $EIRP = P_t G_t$

Power flux density, $\phi = \dfrac{EIRP}{4\pi R^2}$

Received power, $P_r = \phi A_{eff}$

Antenna gain of a circular aperture or reflector of diameter D:

$$G_{\max} = \left(\frac{4\pi}{\lambda^2}\right)A_{eff} = \eta\left(\frac{\pi D}{\lambda}\right)^2 = \eta\left(\frac{70\pi}{\theta_{3dB}}\right)^2, \text{ where } \theta_{3dB} = 70\left(\frac{\lambda}{D}\right)$$

Link Analysis

Noise factor, $F = 1 + \dfrac{T_e}{T_o}$

System noise temperature with reference to the antenna output,

$$T_S = T_{ant} + T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} + \ldots + \frac{T_{en}}{G_1 G_2 \ldots G_{n-1}}$$

Free space loss, $L_{FS} = \left(\dfrac{4\pi R}{\lambda}\right)^2$

$\left[\dfrac{C}{N_0}\right] = [EIRP] + \left[\dfrac{G}{T}\right] - [L] - 10\lg(k)$, noise power spectral density $N_0 = kT$.

$$\frac{N_0}{C} = \left(\frac{N_0}{C}\right)_U + \left(\frac{N_0}{C}\right)_D + \left(\frac{N_0}{C}\right)_{IM}$$

FDM-FM-FDMA Satellite System

Signal bandwidth, $B = 2(gl\Delta f_{rms} + f_{max})$, where $\log_{10} l = \begin{cases} (-1+4\log_{10} n)/20, & n \le 240 \\ (-15+10\log_{10} n)/20, & n > 240 \end{cases}$.

$$\left[\frac{C}{N}\right] = \left[\frac{S}{N}\right] + 10\lg\left(\frac{b}{B}\right) + 20\lg\left(\frac{f_{\max}}{\Delta f_{rms}}\right) - [P] - [W]$$

Appendix II: Table of Complementary Error Function

$$erfc(z) = \frac{2}{\sqrt{\pi}} \int_{z}^{\infty} e^{-t^2} dt \quad \text{for } 0 \le z \le 3.99 \text{ in steps of } 0.01$$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.000E+00	9.887E-01	9.774E-01	9.662E-01	9.549E-01	9.436E-01	9.324E-01	9.211E-01	9.099E-01	8.987E-01
0.1	8.875E-01	8.764E-01	8.652E-01	8.541E-01	8.431E-01	8.320E-01	8.210E-01	8.100E-01	7.991E-01	7.882E-01
0.2	7.773E-01	7.665E-01	7.557E-01	7.450E-01	7.343E-01	7.237E-01	7.131E-01	7.026E-01	6.921E-01	6.817E-01
0.3	6.714E-01	6.611E-01	6.509E-01	6.407E-01	6.306E-01	6.206E-01	6.107E-01	6.008E-01	5.910E-01	5.813E-01
0.4	5.716E-01	5.620E-01	5.525E-01	5.431E-01	5.338E-01	5.245E-01	5.153E-01	5.063E-01	4.973E-01	4.883E-01
0.5	4.795E-01	4.708E-01	4.621E-01	4.535E-01	4.451E-01	4.367E-01	4.284E-01	4.202E-01	4.121E-01	4.041E-01
0.6	3.961E-01	3.883E-01	3.806E-01	3.730E-01	3.654E-01	3.580E-01	3.506E-01	3.434E-01	3.362E-01	3.292E-01
0.7	3.222E-01	3.153E-01	3.086E-01	3.019E-01	2.953E-01	2.888E-01	2.825E-01	2.762E-01	2.700E-01	2.639E-01
0.8	2.579E-01	2.520E-01	2.462E-01	2.405E-01	2.349E-01	2.293E-01	2.239E-01	2.186E-01	2.133E-01	2.082E-01
0.9	2.031E-01	1.981E-01	1.932E-01	1.884E-01	1.837E-01	1.791E-01	1.746E-01	1.701E-01	1.658E-01	1.615E-01
1.0	1.573E-01	1.532E-01	1.492E-01	1.452E-01	1.414E-01	1.376E-01	1.339E-01	1.302E-01	1.267E-01	1.232E-01
1.1	1.198E-01	1.165E-01	1.132E-01	1.100E-01	1.069E-01	1.039E-01	1.009E-01	9.800E-02	9.516E-02	9.239E-02
1.2	8.969E-02	8.704E-02	8.447E-02	8.195E-02	7.949E-02	7.710E-02	7.476E-02	7.249E-02	7.027E-02	6.810E-02
1.3	6.599E-02	6.394E-02	6.193E-02	5.998E-02	5.809E-02	5.624E-02	5.444E-02	5.269E-02	5.098E-02	4.933E-02
1.4	4.771E-02	4.615E-02	4.462E-02	4.314E-02	4.170E-02	4.030E-02	3.895E-02	3.763E-02	3.635E-02	3.510E-02
1.5	3.389E-02	3.272E-02	3.159E-02	3.048E-02	2.941E-02	2.838E-02	2.737E-02	2.640E-02	2.545E-02	2.454E-02
1.6	2.365E-02	2.279E-02	2.196E-02	2.116E-02	2.038E-02	1.962E-02	1.890E-02	1.819E-02	1.751E-02	1.685E-02
1.7	1.621E-02	1.559E-02	1.500E-02	1.442E-02	1.387E-02	1.333E-02	1.281E-02	1.231E-02	1.183E-02	1.136E-02
1.8	1.091E-02	1.048E-02	1.006E-02	9.653E-03	9.264E-03	8.889E-03	8.528E-03	8.179E-03	7.844E-03	7.521E-03
1.9	7.210E-03	6.910E-03	6.622E-03	6.344E-03	6.077E-03	5.821E-03	5.574E-03	5.336E-03	5.108E-03	4.889E-03
2.0	4.678E-03	4.475E-03	4.281E-03	4.094E-03	3.914E-03	3.742E-03	3.577E-03	3.418E-03	3.266E-03	3.120E-03
2.1	2.979E-03	2.845E-03	2.716E-03	2.593E-03	2.475E-03	2.361E-03	2.253E-03	2.149E-03	2.049E-03	1.954E-03
2.2	1.863E-03	1.776E-03	1.692E-03	1.612E-03	1.536E-03	1.463E-03	1.393E-03	1.326E-03	1.262E-03	1.201E-03
2.3	1.143E-03	1.088E-03	1.034E-03	9.838E-04	9.354E-04	8.893E-04	8.452E-04	8.032E-04	7.631E-04	7.249E-04
2.4	6.885E-04	6.538E-04	6.207E-04	5.892E-04	5.592E-04	5.306E-04	5.034E-04	4.774E-04	4.528E-04	4.293E-04
2.5	4.070E-04	3.857E-04	3.655E-04	3.463E-04	3.280E-04	3.107E-04	2.942E-04	2.785E-04	2.636E-04	2.495E-04
2.6	2.360E-04	2.233E-04	2.112E-04	1.997E-04	1.888E-04	1.785E-04	1.687E-04	1.594E-04	1.506E-04	1.422E-04
2.7	1.343E-04	1.268E-04	1.197E-04	1.130E-04	1.066E-04	1.006E-04	9.492E-05	8.952E-05	8.441E-05	7.958E-05
2.8	7.501E-05	7.069E-05	6.661E-05	6.275E-05	5.910E-05	5.566E-05	5.240E-05	4.933E-05	4.642E-05	4.368E-05
2.9	4.110E-05	3.866E-05	3.635E-05	3.418E-05	3.213E-05	3.020E-05	2.838E-05	2.667E-05	2.505E-05	2.353E-05
3.0	2.209E-05	2.074E-05	1.947E-05	1.827E-05	1.714E-05	1.608E-05	1.508E-05	1.414E-05	1.326E-05	1.243E-05
3.1	1.165E-05	1.092E-05	1.023E-05	9.578E-06	8.970E-06	8.398E-06	7.862E-06	7.358E-06	6.885E-06	6.442E-06
3.2	6.026E-06	5.635E-06	5.269E-06	4.926E-06	4.604E-06	4.303E-06	4.020E-06	3.755E-06	3.507E-06	3.275E-06
3.3	3.058E-06	2.854E-06	2.664E-06	2.485E-06	2.319E-06	2.162E-06	2.017E-06	1.880E-06	1.753E-06	1.633E-06
3.4	1.522E-06	1.418E-06	1.321E-06	1.230E-06	1.145E-06	1.066E-06	9.922E-07	9.233E-07	8.590E-07	7.990E-07
3.5	7.431E-07	6.910E-07	6.423E-07	5.970E-07	5.548E-07	5.155E-07	4.788E-07	4.447E-07	4.130E-07	3.834E-07
3.6	3.559E-07	3.303E-07	3.064E-07	2.843E-07	2.636E-07	2.445E-07	2.267E-07	2.101E-07	1.947E-07	1.804E-07
3.7	1.672E-07	1.548E-07	1.434E-07	1.327E-07	1.229E-07	1.137E-07	1.052E-07	9.736E-08	9.005E-08	8.328E-08
3.8	7.700E-08	7.119E-08	6.579E-08	6.080E-08	5.617E-08	5.189E-08	4.792E-08	4.425E-08	4.085E-08	3.770E-08
3.9	3.479E-08	3.210E-08	2.961E-08	2.731E-08	2.518E-08	2.322E-08	2.140E-08	1.972E-08	1.817E-08	1.674E-08

For $z > 4$, $erfc(z) \approx \frac{1}{\sqrt{\pi}} \left(\frac{e^{-z^2}}{z} \right)$

End of Paper